

AMENDMENTS TO THE CLAIMS

All claims and their status are reflected below.

1. -- 54. (cancelled)

55. (Previously presented) A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;

observing the overlaid diffraction gratings using an optical instrument capable of measuring reflectance as a function of wavelength or polarization of illumination and detection using the instrument, or capable of measuring ellipsometric parameters as a function of wavelength of the illumination and detection; and

determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and [the interaction of the gratings with each other's diffracted field.

56. (Previously presented) The method of claim 55 wherein any layers between the grating in layer A and the grating in layer B are at least partially transparent at the wavelength range of the optical instrument.

57. (Previously presented) The method of claim 55 wherein at least one layer between the grating in layer A and the grating in layer B is opaque in the wavelength range of the optical instrument, and the presence of the grating in layer A causes a grating-shaped topography on the surface of the opaque layer.

58. (Previously presented) The method of claim 55 wherein the optical model represents the electromagnetic field in the gratings and in the layers between the gratings as a sum of more than one diffracted orders.

59. (Previously presented) The method of claim 55 wherein offset is determined by: calculating, according to a model of a wafer sample, the optical response of the sample with said two overlapping gratings, the model of the sample taking into account parameters of the sample including any of the overlay misalignment of layers A and B, and a profile parameter of the grating structures; and minimizing the difference between the calculated and measured optical responses

60. (Previously presented) The method of claim 59 wherein at least a portion of the calculated optical response is retrieved from a pre-computed database.

61. (Previously presented) The method of claim 55 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

62. (Previously presented) A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a first patterned layer and a second diffraction grating is built into a second patterned layer, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B, and at least one of the first or second gratings having a repeating pattern consisting of at least two structures of substantially different lateral dimensions;

measuring the optical characteristics of the overlaid diffraction gratings using an optical instrument with a spot size covering portions of the overlapping gratings; and

determining the offset between the gratings from the measured optical characteristics.

63. (Withdrawn) A method of determining a degree of registration between an upper layer and a lower layer formed on a substrate, each of said layers including a periodic structure formed thereon and arranged to at least partially overlap, said method comprising the steps of: illuminating the layers with a probe beam of radiation;

monitoring the zeroth order light diffracted from the layers;
generating a parameterized model representing the geometry and registration of parameters of the model; and
comparing the predicted optical response with the monitored zeroth order light to determine the registration of the structures.

64. (Withdrawn) A method as recited in claim 63 wherein said generating step is at least partially carried out in advance for a number of different parameters and wherein the corresponding responses are stored in a database for later comparison with the monitored response.

65. (Withdrawn) A method as recited in claim 63 wherein said probe beam is generated from a broadband source and said monitoring step is carried out as function of wavelength.

66. (Withdrawn) An apparatus for determining overlay error between two or more patterned layers of a sample, comprising,

a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating built into a patterned layer B, where layers A and B are part of the sample under test and layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;

an optical instrument that illuminates the metrology target and that measures properties of light that has interacted with the metrology target as a function of polarization of the illumination and detection; and

a processor which estimates the offset of the grating pair from the measured properties.

67. (Withdrawn) The apparatus of claim 66 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

68. (Withdrawn) The apparatus of claim 66 wherein at least one other layer of material separates layers A and B at the metrology target.

69. (Withdrawn) The apparatus of claim 66 wherein the optical instrument measures properties of light that has interacted with the metrology target as a function of wavelength.

70. (Withdrawn) The apparatus of claim 66 wherein the processor has been programmed to (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) minimize the difference between the measured properties and the calculated optical response,

wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

71. (Withdrawn) The apparatus of claim 70 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

72. (Withdrawn) An apparatus for determining the overlay error comprising, a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;

an ellipsometer that illuminates the metrology target and that measures properties of light that has interacted with the metrology target; and

a processor which estimates the offset of the grating pair from the pair's measured optical characteristics.

73. (Withdrawn) The apparatus of claim 72 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

74. (Withdrawn) The apparatus of claim 72 wherein at least one other layer of material separates layers A and B at the metrology target.

75. (Withdrawn) The apparatus of claim 72 wherein the ellipsometer measures properties of light that has interacted with the metrology target as a function of wavelength.

76. (Withdrawn) The apparatus of claim 72 wherein the processor has been programmed to (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) minimize the difference between the measured properties and the calculated optical response, wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

77. (Withdrawn) The apparatus of claim 76 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

78. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having:
a first set of gratings,
wherein the first set of gratings are formed on the wafer using a first mask, and
a second set of gratings,
wherein the second set of gratings are formed on the wafer using a second mask,
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and
determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.

79. (Previously presented) The method of claim 78, wherein the measured diffraction signal is a zero-order diffraction.

80. (Previously presented) The method of claim 79, wherein only the zero-order diffraction is measured.

81. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an optical metrology system.

82. (Previously presented) The method of claim 81, wherein the optical metrology system includes an ellipsometer.

83. (Previously presented) The method of claim 81, wherein the optical metrology system includes a reflectometer.

84. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an incident signal with a normal incidence angle.

85. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an incident signal with an oblique incidence angle.

86. (Previously presented) The method of claim 85, wherein the incident signal has an azimuthal angle of zero degrees.

87. (Previously presented) The method of claim 85, wherein measuring the diffraction signal includes:

measuring the amplitude of the diffraction signal.

88. (Previously presented) The method of claim 78 further comprising:
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,

wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.

89. (Previously presented) The method of claim 88 further comprising:
generating a response curve of the correspondence between the different possible misalignments of the first and second sets of gratings and the set of diffraction signals.

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90. (Previously presented) The method of claim 88 further comprising:
determining the intended asymmetric alignment between the first and second sets of gratings based on the generated set of diffraction signals and range of possible alignments.

91. (Previously presented) The method of claim 88, wherein the set of diffraction signals are generated empirically.

92. (Previously presented) The method of claim 88, wherein the set of diffraction signals are generated using modeling.

93. (Previously presented) The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises:
comparing the measured diffraction signal to the generated set of diffraction signals; and
determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

94. (Previously presented) The method of claim 78,
wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and
wherein the ridges of the first and second sets of gratings alternate.

95. (Previously presented) The method of claim 94,
wherein the ridges of the first and second sets of gratings include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings, and
wherein the first and second sets of gratings are symmetrically aligned when the spacing between the centerlines is uniform and asymmetrically aligned when the spacing between the centerlines is non-uniform.

96. (Previously presented)) The method of claim 95, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

97. (Previously presented) The method of claim 78, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

98. (Previously presented) The method of claim 97, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

99. (Previously presented) The method of claim 98, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

100. (Previously presented) The method of claim 78, wherein forming a periodic grating on the wafer comprises:

forming a periodic grating in a first metrology field on the wafer;
forming a periodic grating in a second metrology field on the wafer,
wherein the first and second metrology fields are separated by a distance on the wafer;
obtaining overlay measurements from the first and second metrology fields; and
computing an error based on the obtained overlay measurements.

101. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating, the method comprising:

forming a first set of gratings of the periodic grating on the wafer;
forming a second set of gratings of the periodic grating on the wafer,

wherein the first and second sets of gratings are formed using separate masks, and
wherein the second set of gratings are intended to be formed on the wafer with an
intended asymmetrical alignment from the first set of gratings when the separate masks are in
alignment;

generating a set of diffraction signals for a range of possible misalignments between the
first and second sets of gratings,

wherein each of the diffraction signal in the generated set of diffraction signals
corresponds to a possible misalignment between the first and second sets of gratings;

measuring a diffraction signal of the first and second sets of gratings after the first and
second sets of gratings are formed on the wafer,

wherein the diffraction signal is measured; and

determining a misalignment between the first and second sets of gratings based on the
measured diffraction signal and the generated set of diffraction signals.

102. (Previously presented) The method of claim 101, wherein the determining the
misalignment between the first and second sets of gratings comprises:

comparing the measured diffraction signal to the generated set of diffraction signals; and

determining the possible misalignment that corresponds to the diffraction signal from the
generated set of diffraction signals that matches the measured diffraction signal.

103. (Previously presented) The method of claim 101, wherein the measured
diffraction signal is a zero-order diffraction.

104. (Previously presented) The method of claim 101 further comprising:

generating a plurality of sets of diffraction signals at various wavelengths and/or
polarizations.

105. (Previously presented) The method of claim 101,

wherein the first and second sets of gratings include a plurality of ridges that alternate
with a spacing between the ridges,

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

106. (Previously presented) The method of claim 101,
wherein the first and second sets of gratings include a plurality of ridges with centerlines,
wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

107. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating formed on the wafer, the method comprising:
obtaining the wafer, wherein the period grating on the wafer comprises:
a first set of grating that were formed on the wafer using a first mask,
a second set of gratings that were formed on the wafer using a second mask,
wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;
generating a set of diffraction signals for a plurality of possible misalignments between the first and second sets of gratings;
measuring a diffraction signal of the first and second sets of gratings from the obtained wafer,
wherein the diffraction signal is measured, and
wherein the measured diffraction signal is a zero-order diffraction;
comparing the measured diffraction signal to the generated set of diffraction signals; and
determining an amount and direction of misalignment between the first and second sets of gratings on the obtained wafer based on the possible alignment that corresponds to the diffraction signal from the set of diffraction signals that matches the measured diffraction signal.

108. (Previously presented) The method of claim 107,
wherein the periodic grating on the wafer further comprises: